IDENTIFICATION OF THE INSTREAM FLOW REQUIREMENTS FOR ANADROMOUS FISH IN THE STREAMS WITHIN THE CENTRAL VALLEY OF CALIFORNIA

Annual Progress Report
Fiscal Year 2001

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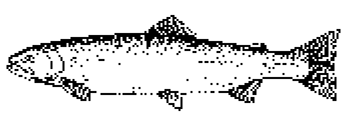



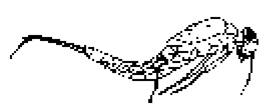

PREFACE

The following is the seventh annual progress report prepared as part of the Central Valley Project Improvement Act Instream Flow Investigations, a 7-year effort which began in February, 1995. Title 34, Section 3406(b)(1)(B) of the Central Valley Project Improvement Act, P.L. 102-575, requires the Secretary of the Interior to determine instream flow needs for anadromous fish for all Central Valley Project controlled streams and rivers, based on recommendations of the U.S. Fish and Wildlife Service (Service) after consultation with the California Department of Fish and Game (CDFG). The purpose of this investigation is to provide reliable scientific information to the Service's Central Valley Project Improvement Act Program to be used to develop such recommendations for Central Valley streams and rivers.

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INTRODUCTION

In response to substantial declines in anadromous fish populations, the Central Valley Project Improvement Act requires the doubling of the natural production of anadromous fish stocks, including the four races of chinook salmon (fall, late-fall, winter, and spring), steelhead trout, and white and green sturgeon. In December 1994, the USFWS, Ecological Services, Instream Flow Assessments Branch prepared a study proposal to use the Service's Instream Flow Incremental Methodology (IFIM) to identify the instream flow requirements for anadromous fish in selected streams within the Central Valley of California. Subsequently, as discussed in our first annual report, the Sacramento, lower American and Merced Rivers were selected for study. In February 1998, the Sacramento Fish and Wildlife Office, Energy, Power and Instream Flow Assessments Branch prepared an updated study proposal. The updated study proposal added other streams, principally Butte Creek, to the above three selected for study. The studies on these rivers have been and will continue to be closely coordinated with study efforts being conducted by CDFG.

The Sacramento River study is a seven-year effort originally scheduled to be concluded in September, 2001. Specific goals of the study are to determine the relationship between streamflow and physical habitat availability for all life stages of chinook salmon (fall-, late-fall-, winter-runs) and to identify flows at which redd dewatering and juvenile stranding conditions occur. The instream flow requirements for white and green sturgeon may also be studied; however, the inclusion of these species depends upon the availability of resources and sufficient data to enable identification of the habitats used by them. The study components include: 1) compilation and review of existing information; 2) consultation with other agencies and biologists; 3) field reconnaissance; 4) development of habitat suitability criteria (HSC); 5) study site selection and transect placement; 6) hydraulic and structural data collection; 7) construction and calibration of reliable hydraulic simulation models; 8) construction of habitat models to predict physical habitat availability over a range of river discharges; and 9) preparation of draft and final reports. The FY 2001 Scope of Work (SOW) identified study tasks to be undertaken. These included: hydraulic and structural data collection (study component 6); construction of hydraulic models (study component 7); and completing the development of HSC (study component 4).

The Lower American River study was a one-year effort which culminated in a March 27, 1996, report detailing the methods and results of this effort. This report was submitted to CDFG for enclosure in their final report on the lower American River. Subsequently, questions arose as to which of the chinook salmon spawning HSC criteria used in the March 27, 1996, report would be transferable to the Lower American River. As a result, additional field work was conducted in FY 1997, culminating in a supplemental report submitted to CDFG on February 11, 1997. As a result of substantial changes in the Lower American River study sites from the January 1997 storms, a second round of habitat data collection and modeling was begun in April 1998. Data collection for this effort was completed in February 1999 and a final report on the Physical Habitat Simulation (PHABSIM) portion of the study was completed on September 29, 2000. A final report on the 2-D modeling portion of the study was scheduled to be completed by September 2001.

The Merced River study was a 1.5 year effort which culminated in a March 19, 1997, report detailing the methods and results of this effort. This report was submitted to CDFG for enclosure in their final report on the Merced River.

The Butte Creek study is a two-year effort which started with collection of spring-run chinook salmon spawning habitat suitability criteria during September 1999. In May 2000, fieldwork was begun to determine the relationship between habitat availability (spawning) and streamflow for spring-run chinook salmon. This fieldwork included study site selection, transect placement and hydraulic and structural data collection. This data collection was completed in May 2001. Collection of spring-run chinook salmon spawning habitat suitability criteria was completed in September 2000.

The following sections summarize project activities between October, 2000 and September, 2001.

SACRAMENTO RIVER

Hydraulic and Structural Data Collection

Juvenile chinook salmon stranding areas

In FY 2001, we continued water surface elevation, discharge, and stranding area data collection for the 107 sites between Keswick Reservoir and Battle Creek located in FY 2000 where stranding flows for juvenile chinook salmon will be identified. One additional stranding site has been identified, bringing the total to 108. The following section describes the methods employed and the results of FY 2001 data collection efforts for this species.

In FY 2001, we determined the areas for 101 of the 108 stranding sites (Appendix A). For smaller sites, we have determined the area by measuring the length and two to six widths of the stranding site, using an electronic distance meter; the area is calculated by multiplying the length times the average width. The areas of larger sites have been measured on aerial photos using a planimeter.

Stage-discharge relationships will be developed for 54 of the 108 stranding sites. Data required for developing a stage-discharge relationship are: 1) water surface elevations (WSELs, stages) collected at three flows; and 2) the stage of zero flow. We also measured the bed elevation of the stranding point (the lowest point at the connection between the stranding area and the main river channel); the stage at the stranding flow was calculated by adding 0.1 feet to the bed elevation of the stranding point. After the stage-discharge relationship is developed, it is used to determine what the flow is at the stranding flow stage. We have measured WSELs at three flows for 53 sites, and at two flows at the remaining site. For most of the sites, the stage of zero flow was determined by making an ADCP run across the main channel at the stranding point. For a few sites on side channels where the entire channel could be waded, the stage of zero flow was determined by measuring depths across the side channel with a wading rod. In both cases, the stage of zero flow was calculated as the difference between the WSEL on that date and the largest depth. We have determined the stage of zero flow and stranding bed elevations for all of the 54 stage-discharge stranding sites. We have completed the stage-discharge relationship and determined the stranding flow for 46 of the 54 stage-discharge stranding sites (Appendix A). We have also determined the stranding flow for 42 of the remaining 54 stranding sites (Appendix A).

Chinook salmon spawning habitat

Hydraulic and structural data collection on the six fall-run chinook salmon spawning sites (Five Fingers Riffle, Blackberry Riffle, Osborne Riffle, Upper Bend Riffle, Jellys Ferry and Mudball Riffle) between Battle Creek and Deer Creek, which began in August 1999, continued in FY 2001 and should be completed in October 2001. As discussed in the FY 1999 progress report, these sites will be modeled using two-dimensional hydraulic and habitat modeling. The 2-D model uses as inputs the bed topography and substrate of a site, and the water surface elevation at the bottom of the site, to predict the amount of habitat present in the site. A PHABSIM transect at the bottom of the site (outflow transect) is used to provide the water surface elevations used by the 2-D model, while the water surface elevations predicted by a PHABSIM transect at the top of the site (inflow transect) are used to calibrate the 2-D model. The data collected at the inflow and outflow transects include: 1) WSELs, measured to the nearest .01 foot at a minimum of three significantly different stream discharges using standard surveying techniques (differential leveling); 2) wetted streambed elevations determined by subtracting the measured depth from the surveyed WSEL at a measured flow; 3) dry ground elevations to points above bankfull discharge surveyed to the nearest 0.1 foot; 4) mean water column velocities measured at a mid-to-high-range flow at the points where bed elevations were taken; and 5) substrate and cover classification at these same locations and also where dry ground elevations were surveyed. Data collected between the transects include: 1) bed elevation; 2) northing and easting (horizontal location); 3) cover; and 4) substrate. These parameters are collected at enough points to characterize the bed topography, substrate and cover of the site.

In FY 2001, we completed collecting WSEL's at all six sites, with the exception of low-flow (approximately 5,000 cfs) WSEL's at Five Fingers; this data will be collected in October 2001. We also completed collection of velocity sets for the transects at all sites in FY 2001. Depth and velocity measurements in portions of the transects with depths greater than three feet were made with the ADCP, while depths and velocity measurements in shallower areas were made by wading with a wading rod equipped with a Marsh-McBirney^{R} model 2000 or a Price AA velocity meter. Dry bed elevations have been collected on the transects at four of the six sites; the data for the remaining two sites (Osborne and Five Fingers) will be collected in October 2001.

Substrate and cover data was collected on the transects at five of the six sites; this task will be completed with the collection of this data for Five Fingers in October 2001. Underwater video equipment and an electronic distance meter were used to determine the substrate and cover along the deeper portions of the transects, with the shallow and dry portions determined visually. The underwater video equipment consists of two cameras mounted on a 75 pound bomb at angles of 45 and 90 degrees. The 75 pound bomb is raised and lowered from our boat using a winch. Two monitors on the boat provide the views from the cameras. A grid on the 90 degree camera monitor calibrated at one foot above the bottom is used to measure the substrate and cover.

Discharge measurements were needed at transects with split channels (Mudball XS 2, Bend XS 2) and for Five Fingers XS 2, to develop relationships between total flow and the flow in each split channel. Discharges for the remaining transects will be determined from gage data. In FY 2001, measurements of discharges for these transects were completed with the exception of low-flow (approximately 5,000 cfs) discharge measurements for Mudball XS 2 and Five Fingers XS 2; this data will be collected in October 2001.

We have used two techniques to collect the data between the top and bottom transects: 1) for areas that were dry or shallow (less than three feet), bed elevation and horizontal location of individual points were obtained with a total station, while the cover and substrate were visually assessed at each point; and 2) in portions of the site with depths greater than three feet, the ADCP was used in concert with the total station to obtain bed elevation and horizontal location. Specifically, the ADCP was run across the channel at 50 to 150-foot intervals, with the initial and final horizontal location of each run measured by the total station. The WSEL of each ADCP run was measured with the level before starting the run. The WSEL of each run was then used together with the depths from the ADCP to determine the bed elevation of each point along the run. Velocities at each point measured by the ADCP will be used to validate the 2-D model. The total station was used to relocate initial and final location of each run. Buoys were placed at these locations for use during the collection of the deep substrate and cover data. The underwater video and electronic distance meter were then used to determine the substrate and cover along each run, so that substrate and cover values could be assigned to each point of the run. To validate the velocities predicted by the 2-D model for shallow areas within a site, depth, velocities, substrate and cover measurements were collected along the right and left banks within each site by wading with a wading rod equipped with a Marsh-McBirney® model 2000 or a Price AA velocity meter. The horizontal locations and bed elevations were determined by taking a total station shot on a prism held at each point where depth and velocity were measured. A minimum of 25 representative points were measured along the length of each side of the river per site.

Collection of both the dry/shallow bed elevation/substrate/cover data and the deep bed elevation data was completed in FY 2000, while the collection of shallow validation velocity data and deep substrate and cover data was completed in FY 2001.

Hydraulic Model Construction and Calibration

Juvenile chinook salmon rearing habitat

The topographic data for the 2-D model (contained in bed files) is first processed using the R2D_Bed software, where breaklines are added to produce a smooth bed topography. The resulting dataset is then converted into a computational mesh using the R2D_Mesh software, with mesh elements sized to reduce the error in bed elevations resulting from the mesh-generating process to 0.1 feet where possible, given the computational constraints on the number of nodes. The resulting mesh is used in River2D to simulate depths and velocities at the flows to be simulated.

The PHABSIM transect at the bottom of each site is calibrated to provide the WSEL's at the bottom of the site used by River2D. The PHABSIM transect at the top of the site is calibrated to provide the water surface elevations used to calibrate the River2D model. The initial bed roughnesses used by River2D are based on the observed substrate sizes and cover types. A multiplier is applied to the resulting bed roughnesses, with the value of the multiplier adjusted so that the WSEL's generated by River2D at the top of the site match the WSEL's predicted by the PHABSIM transect at the top of the site[1]. The River2D model is run at the flows at which the validation dataset was collected, with the output used in GIS to determine the difference between simulated and measured velocities, depths, bed elevations, substrate and cover.

All of the data for the rearing sites between Keswick Dam and Battle Creek have been compiled and checked. PHABSIM data decks have been created and hydraulic calibration has been completed for the upstream and downstream transects for all of the rearing sites between Keswick Dam and Battle Creek. Bed files for the 2-D modeling program have been completed for all of the rearing sites between Keswick Dam and Battle Creek. Computational meshes have been completed for thirteen of the seventeen rearing sites between Keswick Dam and Battle Creek; we are in the process of improving the fit of the mesh to the bed topography for the other four sites. Calibration of the two-dimensional hydraulic models has been completed for five of the rearing sites, while calibration is underway for another four rearing sites. The remaining four rearing sites with completed computational meshes have been unstable with River2D; we are currently examining the use of an alternative two-dimensional hydraulic modeling program (MD_SWMS), developed by the U.S. Geological Survey (USGS) office in Denver, for these sites. Production runs for all of the simulation flows have been completed for three rearing sites and are in process for another rearing site.

[1] This is the primary technique used to calibrate the River2D model.

Habitat Suitability Criteria (HSC) Development

Spawning

Methods

Collection of fall-run spawning HSC data and development of depth, velocity and substrate HSC were completed in FY 2000. Details on criteria and methods are given in U.S. Fish and Wildlife Service 2001.

In FY 2001, we completed our efforts to locate late-fall and winter-run chinook salmon redds in shallow and deep water. We searched for shallow redds on foot and by boat. For both late-fall and winter-run chinook salmon, all of the active redds (those not covered with periphyton growth) within a given mesohabitat unit were measured. Data for shallow redds were collected from an area adjacent to the redd which was judged to have a similar depth and velocity as was present at the redd location prior to redd construction. This location was generally about two to four feet upstream of the pit of the redd; however it was sometimes necessary to make measurements at a 45 degree angle upstream, to the side, or behind the pit. The data were almost always collected within six feet of the pit of the redd. Depth was recorded to the nearest 0.1 ft and average water column velocity was recorded to the nearest 0.01 ft/s. Substrate was visually assessed for the dominant particle size range (i.e., range of 1-2") at three locations: 1) in front of the pit; 2) on the sides of the pit; and 3) in the tailspill. Substrate embeddedness data were not collected because the substrate adjacent to all of the redds sampled was predominantly unembedded. The substrate coding system used is shown in Table 1.

Location of redds in deep water was accomplished by boat using underwater video. Base aerial photos provided by CDFG showing the areas where winter-run chinook salmon redds have been observed in past years were used in locating the primary mesohabitat units where surveys were conducted. When searching for redds in deep water using underwater video, a series of parallel runs with the boat upstream within a mesohabitat unit was performed. After locating a redd in deep water, substrate size was measured using underwater video directly over the redds. Depth and water velocity was measured over the redds using the ADCP. The location of all redds (both in shallow and deep water) was recorded with a Global Positioning System (GPS) unit, so that we could ensure that redds were not measured twice. For the shallow winter-run redds, we also installed numbered metal tags in the tail-spill of each measured redd. These tags were held in place with an 8" carriage bolt and painted red for better visibility. The tags were installed to provide a better means of distinguishing previously measured redds and to assess the accuracy of GPS for distinguishing previously measured redds. All data were entered into spreadsheets for analysis and development of Suitability Indices (HSC).

Table 1
Substrate Descriptors and Codes

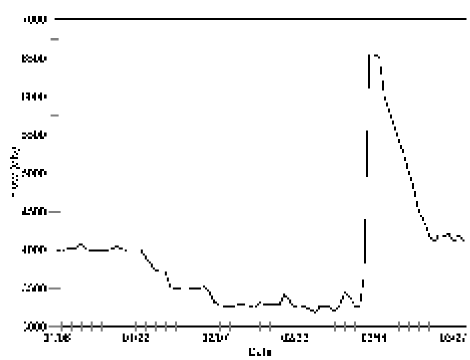
Code	Type	Particle Size (inches)
0.1	Sand/Silt	< 0.1
1	Small Gravel	0.1 - 1
1.2	Medium Gravel	1 - 2
1.3	Medium/Large Gravel	1 - 3
2.3	Large Gravel	2 - 3
2.4	Gravel/Cobble	2 - 4
3.4	Small Cobble	3 - 4
3.5	Small Cobble	3 - 5
4.6	Medium Cobble	4 - 6
6.8	Large Cobble	6 - 8
8	Large Cobble	8 - 12
9	Boulder/Bedrock	> 12

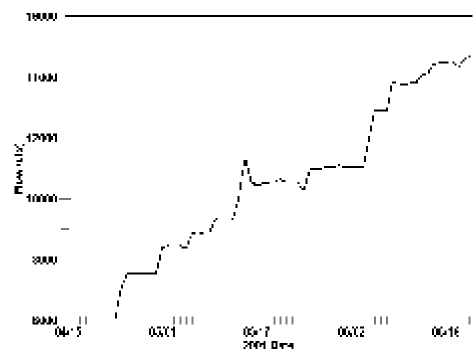
Surveys for shallow and deep late-fall-run chinook salmon redds were conducted on February 27-March 1, March 5-6, and March 29. The data on all but three redds was collected from February 27 to March 6. Sacramento River flows (releases from Keswick Reservoir) averaged 3,577 cfs, ranging from 3,187 to 4,080 cfs, from January 6 through March 6, 2001. Since few late-fall-run salmon had started constructing redds prior to January 6, these steady flow conditions ensured that the measured depths and velocities were likely the same as present at the time of redd construction. In contrast, flows from March 6 to 29, 2001 ranged from 3,267 to 6,546 cfs (Figure 1), adding a measure of uncertainty to the limited data collected on March 29, 2001, since we can not be certain that the depths and velocities measured were similar to those during redd construction.

HSC data were collected on winter-run chinook salmon redds on June 4-7 and June 19-22, 2001. Sacramento River flows (releases from Keswick Reservoir) varied considerably, from 6,049 to 14,669 cfs (Figure 2) from the initiation of winter-run spawning in mid-April through the end of sampling.

Figure 1 Figure 2

2001Keswick Releases





As described for the late-fall chinook salmon spawning, this adds a measure of uncertainty to HSC to be developed from this data. Only 10% of the redds had fish holding on them (an indication of recent redd construction). Given the low population numbers of winter-run, it was necessary to use data from this year despite the uncertainty in the data.

<u>Results</u>

HSC data were collected on a total of 77 late-fall chinook salmon redds. We spent an equal number of days sampling in shallow (less than 3 feet) and deep areas for our late-fall-run chinook salmon spawning HSC data collection. Thirty-one mesohabitat units were sampled (five Bar Complex (BC) Riffles, four BC Runs, two BC Glides, two BC Pools, four Flat Water (FW) Runs, two FW Riffles, six FW Glides, one FW Pool, four Side Channel (SC) riffles and one SC Run). Of the 31 units sampled, late-fall redds were found in fourteen (two FW Riffles, two FW Runs, one FW Pool, five FW Glides, one BC Riffle, one BC Run, one BC Glide and one SC Riffle) mesohabitat units (Table 2).

The HSC data had depths ranging from 0.3 to 9.7 feet, velocities ranging from 0.32 to 5.84 ft/s, and substrate sizes ranging from 0.1-1 inches to 4-6 inches. Because this chinook race spawns during the peak of the winter/early spring storm season (January through mid-April) when river flows are often very high and erratic, we have been unable to collect HSC data in previous years. This made it impossible to collect data on the 150 redds that is considered the desired minimum when developing HSC. Due to the fact that less than 150 redd observations were made during the course of the study, HSC for late-fall chinook salmon spawning were developed by combining the data collected in 2001 with data that were collected by CDFG from 1986 to 1988. More information about the late-fall chinook salmon spawning HSC and how they were developed is provided in U.S. Fish and Wildlife Service 2001.

Table 2
2001 Late Fall-Run Redd Locations

Location	Number of Redds
Upper Lake Redding	20
Lower Lake Redding	9
Bridge Riffle	2
Posse Grounds (Mesohabitat Units 135 and 136)	13
Mesohabitat Unit 131 (River Mile 297.2)	2
Mesohabitat Unit 129 (River Mile 296.8)	6
Turtle Bay Side Channels (Mesohabitat Unit 128)	6
Mesohabitat Unit 122 (River Mile 296)	4
Mesohabitat Unit 109 (River Mile 294.5)	1
Mesohabitat Unit 105 (River Mile 293.2)	1
Golf Course Riffle	2
Tobiasson Riffle	5
Above Hawes Hole	5

The number of winter-run chinook salmon and redds observed this year was much higher than in the previous years of this study, with HSC data collected on a total of 116 redds (53 shallow and 63 deep redds). In the years prior to FY 2001, HSC data had been collected on a total of 111 redds. In FY 2001, a total of 21 mesohabitat units were sampled (two Side Channel (SC) Riffles, three BC Runs, three BC Glides, three BC Riffles, five FW Glides, two FW Riffles, three FW Runs, and two FW Pools). The above mesohabitat units are areas where winter-run redds have been observed between Keswick Dam and Battle Creek in past aerial redd surveys. Of the 21 mesohabitat units surveyed, winter-run redds were found in eighteen (two FW Riffle, three BC Riffles, three BC Runs, two FW Runs, two SC Riffles, four FW Glides, one FW Pool, and one BC Glide) habitat units (Table 3). Information is provided in U.S. Fish and Wildlife Service 2001 about the HSC that were developed by combining this data with data we collected during 1996, and 1998-2000.

Table 3
2001 Winter-Run Redd Locations

Location	Number of Redds
Mesohabitat Unit 148 (River Mile 300.6)	5
Upper Lake Redding	4
Bridge Riffle	11
Posse Grounds (Mesohabitat Units 135 and 136)	18
Mesohabitat Unit 133 (River Mile 297.3)	7
Mesohabitat Unit 132 (River Mile 297)	4
Mesohabitat Unit 131 (River Mile 297)	7
Turtle Bay Side Channels (Mesohabitat Unit 128)	11
Mesohabitat Unit 124 (River Mile 296.4)	2
Mesohabitat Unit 123 (River Mile 296.3)	3
Mesohabitat Unit 122 (River Mile 296.1	11
Mesohabitat Unit 111 (River Mile 295)	2
Mesohabitat Unit 109 (River Mile 294.5)	1
Mesohabitat Unit 104 (River Mile 292.7)	6
Tobiasson Riffle	18
Mesohabitat Unit 84 (River Mile 289.8)	5
Mesohabitat Unit 81 (River Mile 290)	1

The tags that we used to mark the location of winter-run redds in 2001 did not prove to be very effective. During the second week of sampling, we were only able to relocate 15 out of 33 tags that were placed during the first week of sampling. Flows had increased from an average of 12,261 cfs during the first week of sampling to 14,523 cfs during the second week of sampling. As a result, some of the tags could not be located because the depth and velocity had become too deep and fast to wade. Also, the higher flows may have moved gravel around, burying some of the tags. Some of the tags may also have been buried by redds constructed between the two sampling weeks. Of the tags that we relocated, the distance from the location indicated by the GPS unit to the pit of the marked redd ranged from 0 to 15 feet, averaging 7 feet. Accordingly, it appears that the GPS unit was relatively accurate in distinguishing previously measured redds.

Rearing

The collection of chinook salmon fry and juveniles (YOY) rearing HSC data was completed in FY 2001, with data collected on October 10-13, 2000, March 26-28, 2001, May 21-24, 2001, and August 14-17, 2001. Keswick releases were approximately 6,500 cfs during the October 2000 surveys, approximately 4,000 cfs during the March 2001 surveys, approximately 10,500 cfs during the May 2001 surveys and approximately 11,000 cfs during the August 2001 surveys. As in previous years, data were collected in areas adjacent to the bank. We continued a greater emphasis on scuba surveys of deeper water mesohabitat areas in FY 2001 to try to equalize overall sampling effort between shallow and deep areas.

When conducting snorkeling surveys adjacent to the bank, one person snorkeled upstream along the bank and placed a weighted, numbered tag at each location where YOY chinook salmon were observed. The snorkeler recorded the tag number, the cover code[2] and the number of individuals observed in each 10-20 mm size class on a PVC wrist cuff. Cover availability in the area sampled (percentage of the area with different cover types) and the length of bank sampled (measured with a 300' tape) was also recorded. Another individual retrieved the tags, measured the depth and mean water column velocity at the tag location, and recorded the data for each tag number. Depth was recorded to the nearest 0.1 ft and average water column velocity was recorded to the nearest 0.01 ft/s. An adjacent mean water column velocity was also measured within two feet[3] on either side of the tag where the velocity was the highest. This measurement was taken to provide the option of using an alternative habitat model which considers adjacent velocities in assessing habitat quality. Adjacent velocity can be an important habitat variable as fish, particularly fry and juveniles, frequently reside in slow-water habitats adjacent to faster water where invertebrate drift is conveyed. Both the residence and adjacent velocity variables are important for fish to minimize the energy expenditure/food intake ratio and maintain growth. Data taken by the snorkeler and the measurer were correlated at each tag location.

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[2] If there was no cover elements (as defined in Table 4) within one foot horizontally of the fish location, the cover code was 0 (no cover).

[3] Two feet was selected based on a mechanism of turbulent mixing transporting invertebrate drift from fast-water areas to adjacent slow-water areas where fry and juvenile salmon reside, taking into account that the size of turbulent eddies is approximately one-half of the mean river depth (Terry Waddle, USGS, personal communication), and assuming that the mean depth of the Sacramento River is around four feet (ie., four feet x ½ = two feet).

Table 4
Cover Coding System

Cover Category	Cover Code[4]
no cover	0
cobble	1
boulder	2
fine woody vegetation (< 1" diameter)	3
branches	4
log (> 1' diameter)	5
overhead cover (< 2' from water surface)	7
undercut bank	8
aquatic vegetation	9
rip-rap	10

Scuba surveys of deep water mesohabitat areas were conducted by first anchoring a rope longitudinally upstream through the area to be surveyed to facilitate upstream movement by the divers and increase diver safety. Two divers entered the water at the downstream end of the rope and proceeded along the rope upstream using climbing ascenders. One diver concentrated on surveying the water below and to the side, while the other diver concentrated on surveying the water above and to the side. When a juvenile salmon was observed, a weighted buoy was placed by the divers at the location of the observation. The cover code and the number of individuals observed in each 10-20 mm size class was then recorded on a PVC wrist cuff. Cover availability in the area sampled (percentage of the area with different cover types) and the length of river sampled (measured with the electronic distance meter) were also recorded. After the dive was completed, individuals in the boat retrieved each buoy and measured the water velocity and depth over that location with the ADCP. For each set of data collected using the ADCP for a juvenile fish observation, the average depth and velocity are considered the depth and velocity, while the maximum velocity is considered the adjacent velocity.

[4] In addition to these cover codes, we have been using the composite cover codes 3/7, 4/7, 5/7 and 9/7; for example, 4/7 would be branches plus overhead cover.

All YOY chinook salmon observed have been classified by race according to a table provided by CDFG correlating race with life stage periodicity and total length. Data were also compiled on the length of each mesohabitat and cover type sampled to ensure that equal effort would eventually be spent in each mesohabitat and cover type and that each location was only sampled once at the same flow (to avoid problems with pseudo-replication).

We continued the process, begun during the April 2000 surveys, of also collecting depth, velocity, adjacent velocity and cover data on locations which were not occupied by juvenile chinook salmon (unoccupied locations). This was done so that we could apply a method presented in Rubin et al. (1991) to explicitly take into account habitat availability in developing HSC criteria, without using preference ratios (use divided by availability). Traditionally criteria are created from observations of fish use by fitting a nonlinear function to the frequency of habitat use for each variable (depth, velocity, cover, adjacent velocity). One concern with this technique is what effect the availability of habitat has on the observed frequency of habitat use. For example, if cover is relatively rare in a stream, fish will be found primarily not using cover simply because of the rarity of cover, rather than because they are selecting areas without cover. Rubin et al. (1991) proposed a modification of the above technique where depth, velocity, cover and adjacent velocity data are collected both in locations where fish are present and in locations where fish are absent. Criteria are then developed by using a nonlinear regression procedure (suited to data with a Poisson distribution) with number of fish as the dependent variable and depth, velocity, cover and adjacent velocity as the independent variables, and all of the data (in both occupied and unoccupied locations) are used in the regression. An alternative approach is to use a logistic regression procedure, with the only difference being that the dependent variable is the presence or absence of fish. The HSC sampling methods presented above were modified as follows to allow for the collection of juvenile HSC data from both occupied locations (same method as above) and unoccupied locations.

Before going out into the field, a data book was prepared with one line for each unoccupied location where depth, velocity, cover and adjacent velocity would be measured. Each line had a distance from the bank, with a range of 0.5 to 10 feet by 0.5 foot increments, with the values produced by a random number generator.

One person snorkeled upstream along the bank in the same method as described above dropping tags at locations of juvenile salmon. Two additional items were recorded by the snorkeler: the average and maximum distance from the water’s edge that was sampled. A 300' tape was put out with one end tied at the location where the snorkeler finished and the other end loose with a small buoy attached. Three people went up the tape, one with a stadia rod and data book and the other two with a wading rod and velocity meter. At every 10' along the tape, the person with the stadia rod measured out the distance from the bank given in the data book. If there was a tag within 3' feet of the location, “tag within 3'” was recorded on that line in the data book and the people proceeded to the next 10' mark on the tape, using the distance from the bank on the next line. If the location was beyond the sampling distance, based on the information recorded by the snorkeler, "beyond sampling distance" was recorded on that line and the recorder went to the next line at that same location, repeating until reaching a line with a distance from the bank within the sampling distance. If there was no tag within 3' of that location, one of the people with the wading rod measured the depth, velocity, adjacent velocity and cover at that location. A fourth person followed behind and measured the depth, velocity and adjacent velocity at each tag location.

For areas that were sampled with SCUBA, the ADCP was turned on as we started to pull in the rope after the dive. The boat followed the course of the dive as the rope was pulled back into the boat. If there were any observations during the dive, the ADCP was stopped three feet before the location of the observation and started again three feet after the location of the observation. The ADCP was turned off at the location where the dive ended. A random number generator was used to select ADCP measurements of depth and velocity for unoccupied locations. The number of unoccupied cells selected for each site was the lesser of either 10% of the total distance (feet) sampled or 30% of the total number of ADCP points. For the SCUBA data, cover was assigned to all of the observations in proportion to which they were observed during the dive. The adjacent velocity for each unoccupied location was the largest of the three following values: the velocity at the location immediately prior to the unoccupied location, the velocity at the unoccupied location, and the velocity at the location immediately after the unoccupied location.

The data for both occupied and unoccupied locations described above were combined with the previously-collected data on habitat use, and the resulting data set will be used to develop criteria as described above using either a nonlinear regression or logistic regression method.

Results

We collected a total of 999 measurements of cover, 998 measurements of depth, 996 measurements of velocity and 994 measurements of adjacent velocity where YOY chinook salmon were observed. All but 36 of these measurements were made near the river banks. There were 515 observations of fish less than 40 mm, 632 observations of 40-60 mm fish, 171 observations of 60-80 mm fish and 54 observations of fish greater than 80 mm[5]. According to the race classification table, these numbers account for 493 fall-run, 483 late fall-run, 6 spring-run, and 273 winter-run YOY chinook salmon observations. A total of 14.4 miles of near-bank habitat and 10.0 miles of mid-channel habitat were sampled. Table 5 summarizes the number of feet of different mesohabitat types sampled and Table 6 summarizes the number of feet of different cover types sampled. We sampled 54,827 feet of cover group 0 and 21,307 feet of cover group 1 in near-bank habitats, and 50,640 feet of cover group 0 and

[5] These numbers total much more than 999 because most of the observations included YOY of several size classes and only one measurement was made per group of closely associated individuals.

Table 5
Distances (feet) Sampled for Juvenile Chinook Salmon HSC Data - Mesohabitat Types

Mesohabitat Type	Near-bank habitat distance sampled	Mid-channel habitat distance sampled (ft)
Bar Complex Glide	6,385	5,370
Bar Complex Pool	5,756	5,215
Bar Complex Riffle	8,796	1,230
Bar Complex Run	8,770	2,126
Flatwater Glide	10,923	8,391
Flatwater Pool	3,534	1,500
Flatwater Riffle	5,712	1,200
Flatwater Run	8,286	11,713
Off-Channel Area	900	0
Side-Channel Riffle	7,995	270
Side-Channel Run	3,700	0

Table 6
Distances (feet) Sampled for Juvenile Chinook Salmon HSC Data - Cover Types

Cover Type	Near-bank habitat distance sampled (ft)	Mid-channel habitat distance sampled (ft)
None	15,100	13,153
Cobble	20,734	16,127
Boulder	3,473	2,259
Fine Woody	8,782	222
Branches	11,541	841
Log	2,126	365
Overhead	1,476	0
Undercut	1,766	0
Aquatic Vegetation	4,852	1,143
Rip Rap	908	6
Overhead + instream	15,230	667

2,625 feet of cover group 1 in mid-channel habitats[6]. We made 1,789 measurements for unoccupied locations (592 in shallow areas and 1,197 in deep areas). Depths at locations where YOY chinook salmon were observed ranged from 0.2 to 23.7 feet, while velocities ranged from 0 to 3.92 ft/s and adjacent velocities ranged from 0 to 4.53 ft/s. HSC criteria for YOY chinook salmon will be developed in FY 2002.

Macroinvertebrate Criteria

We are developing a second set of juvenile chinook salmon HSC - one based on food supply rather than physical habitat. Specifically, we are developing HSC for macroinvertebrate biomass and diversity. The criteria we develop will be run on the juvenile rearing site habitat models to predict the relationship between flow and habitat area for macroinvertebrate biomass and diversity. Macroinvertebrates were collected in a surber sampler with a 9-square-foot sampling area. The sampler was four-feet-high, so it could be used to sample areas with depths up to four feet. The sampler consisted of a steel-rod frame with fine-mesh seine material on the sides and brackets for a detachable net on the back. The net had a 3'x4' opening, a mesh size of 600 μm, and is mounted on a rectangular 3'x4' steel frame. The bottom of the sampler had a rubber foam lining to provide a tight seal with the substrate when the sampler was pressed down to the river bottom. The sampler required three individuals - one to hold the sampler in place, and the other two individuals to clean off rocks within the 9-square-foot area, with the current carrying the macroinvertebrates into the net. Rocks were cleaned to a depth of four to six inches. Bedrock was cleaned with a 3"x6" scrub brush, while rocks were picked up and cleaned underwater by rubbing with neopreme gloves. Sites less than three feet deep were sampled by two individuals with snorkel gear, while sites over three feet were sampled by one individual with scuba gear. After sampling was completed, the net was detached from the sampler, the macroinvertebrates in the net were washed into the cod end of the net and then transferred to jars with 70% alcohol for transport back to the lab for analysis.

We stratified our sampling by season, habitat type, depth, velocity and substrate. Specifically, for each two-week sampling period, we attempted to collect one sample in each combination of 1-foot increments of depth (up to 4 feet), 1-foot/sec increments of velocity (up to 4 feet/sec) and five ranges of substrate size, and to collect equal numbers of samples in riffle, run, glide and pool mesohabitat types. Sampling sites were selected based on the above stratification protocol with a tag placed at the sampling location. Before a sample was collected, the depth and mean column velocity at the sampling site were measured and the substrate size noted. To eliminate potential effects on the

[6] As discussed in our FY 1998 annual report, we grouped our cover codes into two groups; cover codes within each group are not statistically significantly different, while cover codes between the two groups are statistically significantly different. Cover group 0 consists of cover codes 0, 1, 2, 3, 5, 8, 9, and 10, while cover group 1 consists of cover codes 4, 7, 3/7, 4/7, 5/7 and 9/7.

macroinvertebrate population due to changes in flow, we required at least 30 days of stable discharge from Keswick Dam prior to sample collection. Our original sampling plan was to collect samples once every three months. However, frequent fluctuations of Keswick Dam releases during most of the year typically only left two periods which have relatively constant flows for 30 days: mid-summer, typically starting around early July; and mid-fall, typically starting around early October. Thus the only times suitable for sampling were in mid-August and mid-November. However, relatively constant flows from Keswick Dam extended into the winter of 2000-2001, allowing additional sampling to occur in December 2000 and January 2001.

We have completed our sampling, having collected a total of 75 macroinvertebrate samples (twenty-two in riffles, twenty in runs, thirteen in pools and twenty in glides). Ten samples were collected in FY 1999 (in July), and twenty-seven samples were collected in FY 2000. During FY 2001, fourteen samples were collected in November 2000, twelve samples were collected in December 2000, and twelve samples were collected in January 2001. Keswick releases in the month prior to the November 2000 sampling averaged 5,418 cfs ± 18%, while Keswick releases in the month prior to the December 2000 sampling averaged 5,405 cfs ± 6%. During the month prior to the January 2001 sampling, Keswick releases averaged 4,390 ± 9%. Depths of the samples ranged from 0.8 to 4.3 ft, while the velocities of the samples ranged from 0.40 to 4.86 ft/s. Samples were collected for the entire range of substrate types in Table 1, ranging from sand/silt to bedrock.

Having completed our sampling, we are now working on sorting, identifying and enumerating the samples. To date, we have completed initial processing of 21 out of 75 samples, separating macroinvertebrates from detritus. These samples are ready to have their biomass measured. We will then determine the relative biomass and diversity represented by each sample. HSC will be developed for macroinvertebrate production and diversity as determined by depth, velocity, and substrate size based on the relative biomass and diversity determined for the samples. Given the stratification of the sampling by depth, velocity and substrate, the 75 samples collected should be sufficient to generate habitat suitability criteria.

LOWER AMERICAN RIVER

As a result of the 115,000 cfs flood releases made into the lower American River in January of 1997, considerable morphological changes have occurred in many areas of the river including some of our previous study sites. Consequently, CDFG requested that we collect additional hydraulic and structural data, and develop new spawning habitat models for fall-run chinook salmon on the lower American River.

We decided to run both PHABSIM and the 2-D habitat modeling program funded by the USGS office in Fort Collins, Colorado, to allow for additional comparisons of the 2-D model to PHABSIM. The 2-D model uses as inputs the bed topography and substrate of a site, and the water surface elevation at the bottom of the site, to predict the amount of habitat present in the site. We are in the process of running the 2-D model for each of the five study sites described in the FY 1998 annual report. The downstream-most PHABSIM transect was used as the bottom of the site, to provide WSEL's as an input to the 2-D model. The upstream-most PHABSIM transect was used as the top of the site. To calibrate the 2-D model, bed roughnesses were adjusted until the WSEL at the top of the site matched the WSEL predicted by PHABSIM.

In FY-2001, we used the PHABSIM modeling results to conduct a redd dewatering analysis for both fall-run chinook salmon and steelhead trout. The methods and results of this analysis are in Appendix B.

Hydraulic Model Construction and Calibration

All of the data for the five lower American River spawning sites have been compiled and checked. PHABSIM data decks have been created and hydraulic calibration has been completed for the lower American River spawning site transects. A final report on the PHABSIM portion of the lower American River study was completed in September 2000. Bed files and computational meshes for the 2-D modeling program have been completed for all of the lower American River spawning sites. Production runs have been completed for one of the sites and are in process for another two sites; we are still in the process of calibrating the remaining two sites. A final report on the 2-D modeling portion of the lower American River study will be completed by the end of December 2001.

BUTTE CREEK

Habitat Suitability Criteria (HSC) Development

Spawning

<u>Methods</u>

We collected habitat suitability criteria data for spring-run chinook salmon spawning on September 26-27, 2000 and October 2-5, 2000, in segments of Butte Creek between Centerville Head Dam and Parrot Phelan Dam where substantial spawning was found in 1999. Habitat suitability criteria data were also collected in the seven study sites established in FY 2000 that were selected based on being among those which received the heaviest use by spawning spring-run salmon in 1999 (Table 7).

Depth, velocity, and substrate size were collected for each redd and the number of redds were counted. Flows in the portion of Butte Creek between Centerville Head Dam and Centerville Powerhouse were stable at 40 cfs from the beginning of spring-run spawning (September 1) until the end of habitat suitability data collection. These steady flow conditions ensured that the measured

Table 7
Sites Selected for Modeling Spring-run Chinook Salmon Spawning

Site Name	Reach	Number of Redds 1999	Number of Redds 2000
Whiskey Flat	Centerville Head Dam - Centerville Powerhouse	13	29
Above Helltown 1	Centerville Head Dam - Centerville Powerhouse	30	40
Above Helltown 2	Centerville Head Dam - Centerville Powerhouse	>80	90
Helltown Bridge	Centerville Head Dam - Centerville Powerhouse	39	34
Homestead	Centerville Powerhouse - Parrot Phelan Dam	18	16
Richbar	Centerville Powerhouse - Parrot Phelan Dam	58	72
Tailings	Centerville Powerhouse - Parrot Phelan Dam	28	22

depths and velocities were likely the same as those present at the time of redd construction. However, flows below Centerville Powerhouse increased from 197 cfs on September 1 to 223 cfs on September 2-3 and thereafter gradually decreased to 184 cfs on September 17. Flows were decreased further to 131 cfs on September 19 and remained at approximately 135 cfs for the remainder of the period during which habitat suitability criteria data were collected. The unstable nature of the flows downstream of Centerville Powerhouse from the beginning of the spring-run spawning resulted in some uncertainty that the measured depths and velocities in the section from Centerville Powerhouse to Parrot Phelan Dam were the same as those present at the time of redd construction. However, CDFG personnel conducting weekly carcass counts on Butte Creek noted that there was little spawning activity downstream of Centerville Powerhouse prior to September 19. Accordingly, it is likely that most of the redds that we measured below Centerville Powerhouse were constructed at a flow close to that at the time the HSC data was collected, and thus that the measured depths and velocities were the same as those present at the time of redd construction.

For habitat suitability criteria data collection, all of the active redds (those not covered with periphyton growth) which could be distinguished were measured. Data were collected from an area adjacent to the redd which was judged to have a similar depth and velocity as was present at the redd location prior to redd construction. This location was generally about two to four feet upstream of the pit of the redd; however it was sometimes necessary to make measurements at a 45 degree angle upstream, to the side, or behind the pit. The data were almost always collected within six feet of the pit of the redd. Depth was recorded to the nearest 0.1 ft and average water column velocity was recorded to the nearest 0.01 ft/s. Substrate was visually assessed for the dominant particle size range (i.e., range of 1-2") at three locations: 1) in front of the pit; 2) on the sides of the pit; and 3) in the tailspill. Substrate embeddedness data were not collected because the substrate adjacent to all of the redds sampled was predominantly unembedded. The substrate coding system used is shown in Table 1. The locations of all redds measured were recorded with a total station within the seven study sites, and with GPS in all other areas, so that we could ensure that redds were not measured twice. The redd location data for the study sites will also be used to validate the habitat predictions of the two-dimensional models of the study sites.

Results

In FY 2001, we collected habitat suitability criteria for 193 spring-run chinook salmon redds between Centerville Head Dam and Centerville Powerhouse, making a combined total of 585 redds for FY 2000-2001. We collected habitat suitability criteria for 207 spring-run chinook salmon redds between Centerville Powerhouse and Parrot Phelan Dam in FY 2001. All data were entered into spreadsheets for eventual analysis and development of Suitability Indices (HSC).

Hydraulic and Structural Data Collection

The modeling of spring-run chinook salmon spawning habitat will be accomplished using two-dimensional modeling. The 2-D model uses as inputs the bed topography and cover of a site, and the water surface elevation at the bottom of the site, to predict the amount of habitat present in the site. The 2-D model avoids problems of transect placement, since the entire mesohabitat unit can be modeled. The 2-D model also has the potential to model depths and velocities over a range of flows more accurately than PHABSIM because it takes into account upstream and downstream bed topography and bed roughness, and explicitly uses mechanistic processes (conservation of mass and momentum), rather than Manning's n and a velocity adjustment factor. Other advantages of 2-D modeling are that it can explicitly handle complex habitats, including transverse flows, across-channel variation in water surface elevations and flow contractions/expansions. The model scale is small enough to correspond to the scale of microhabitat use data with depths and velocities produced on a continuous basis, rather than in discrete cells. The 2-D model does a better job of representing patchy microhabitat features, such as gravel patches. The data can be collected with a stratified sampling scheme, with higher intensity sampling in areas with more complex or more quickly varying microhabitat features, and lower intensity sampling in areas with uniformly varying bed topography and uniform substrate and cover. Bed topography and substrate/cover mapping data can be collected at a very low flow, with the only data needed at high flow being WSEL's at the top and bottom of the site and the flow and edge velocities for validation purposes. Only limited velocity data is required for validation purposes. In addition, alternative habitat suitability criteria, such as measures of habitat diversity, can be used.

Hydraulic and structural data collection were completed in May 2001 for the seven sites that were established in FY 2000. The data collected at the inflow and outflow transects include:
1) WSEL's, measured to the nearest .01 foot at a minimum of three significantly different stream

discharges using standard surveying techniques (differential leveling); 2) wetted streambed elevations determined by subtracting the measured depth from the surveyed WSEL at a measured flow; 3) dry ground elevations to points above bankfull discharge surveyed to the nearest 0.1 foot; 4) mean water column velocities measured at a mid-to-high-range flow at the points where bed elevations were taken; and 5) substrate and cover classification at these same locations and also where dry ground elevations were surveyed. Data collected between the transects include: 1) bed elevation; 2) northing and easting (horizontal location); 3) cover; and 4) substrate. These parameters are collected at enough points to characterize the bed topography, substrate and cover of the site.

The collection of WSEL's was completed in FY 2001 with the measurement of water surface elevations at a medium flow (241 cfs) at the three sites between Centerville Powerhouse and Parrot Phelan Dam. The stage of zero flow value was measured for all sites. We completed tying together vertical benchmarks for all sites in FY 2001 with the tying together of the vertical benchmarks at Richbar. Collection of substrate, cover and dry bed elevation data was completed in FY 2000.

We have collected the data between the top and bottom transects by obtaining the bed elevation and horizontal location of individual points with a total station, while the cover and substrate are visually assessed at each point. To validate the velocities predicted by the 2-D model, depth, velocities, substrate and cover measurements were collected by wading with a wading rod equipped with a Marsh-McBirney[R] model 2000 or a Price AA velocity meter. The horizontal locations and bed elevations were determined by taking a total station shot on a prism held at each point where depth and velocity were measured. A minimum of 50 representative points were measured per site. Bed topography data for all sites was completed in FY 2001 with the collection of bed topography data for Helltown Bridge and Richbar. Collection of validation velocity data was completed in FY 2000.

Hydraulic Model Construction and Calibration

All data for the spawning habitat sites have been compiled and checked, and PHABSIM data decks, hydraulic calibration and final 2-D modeling files for the seven sites will be completed for all sites by the end of FY 2002.

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APPENDIX A

SACRAMENTO RIVER JUVENILE CHINOOK SALMON STRANDING SITES

Stranding Site #	River Mile	River Bank	MHU #	Stranding Flow (cfs)[7]	Stranding Area (ft^2)
1	298.8	Left	139	21,250/5,000	19,579
2	300.5	Left	142		200
3A	300.6	Left	143	12,750/11,100	684
3B	300.6	Left	143	5,200/4,625	2,673
4	300.8	Left	143	7,400/6,580	4,838
5	301.4	Left	143	20,000/4,825	2,107
6	302.0	Right	143	8,128	1,200
7	300.2	Right	141	5,250/<3,250	2,850
8	299.9	Right	140	8,200/5,100	12,906
9	292.5	Left	100	6,409	1,319
10	294.0	Left	109	5,950	600
11	295.2	Left	113	<3,250	---
12	295.2	Left	113	<3,250	8,303
13	296.4	Left	129	4,500	1,056
14	296.5	Left	127	4,555	200,000
15	297.0	Left	127	<3,250	5,373
16	297.4	Left	133	<3,250	75,024
17	296.9	Right	132	4,844	1,296
18	296.7	Right	130		
19	296.3	Right	123	5,950	3,164
20	295.5	N/A	114	9,337	13,640
21	295.3	N/A	114	6,050	47,611

[7] Sites 1 to 5, 7 and 8 are located above ACID and have a different stranding flow depending on whether the boards are in or out at ACID. The first flow is the stranding flow with boards out, while the second flow is the stranding flow with boards out.

Stranding Site #	River Mile	River Bank	MHU #	Stranding Flow (cfs)	Stranding Area (ft^2)
22	294.9	Right	111	<3,250	594
23	291.7	Right	96	4,360	4,497
24	291.8	Left	97	6,032	2,640
25	291.8	Right	97	4,248	5,612
26	289.5	Right	80		
27	293.7	N/A	107	3,946	106,000
28	293.7	Right	109	<3,250	1,352
29	293.7	Right	108	7,483	300
30	293.1	Right	104	5,921	26,978
31	292.8	Right	104	14,276	580
32	292.8	Right	104	7,683	26,371
33	291.5	Right	91	14,927	21,500
34	290.3	Right	85	5,934	11,606
35	289.3	Middle	75	7,898	4,397
36	289.3	Middle	75	3,450	36,320
37	288.5	Right	67	<3,250	4,700
38	288.5	Right	67	13,771	429
39A	291.7	Left	98	4,752	4,118
39B	291.7	Left	98	10,508	533
40	291.4	Left	91	10,747	13,739
41	290.3	Left	85	7,330	5,921
41A	290.3	Left	85	4,640	3,233
42	290.3	Left	85	7,683>Q>4,710	3,050
43	290.3	Left	85	4,440	9,020
44	290.0	Left	85	9,514	18,631

Stranding Site #	River Mile	River Bank	MHU #	Stranding Flow (cfs)	Stranding Area (ft^2)
45A	290.0	N/A	84	<3,250	2,649
45B	290.0	N/A	84	3,502	
46	289.8	N/A	83	4,108	34,126
47	289.5	Left	81		432
48	289.4	Left	75	8,277	333
49	289.8	Left	83	4,640	5,066
50	289.6	N/A	82	4,440	40,594
51	289.5	N/A	78-80&82	3,502	345,115
52	289.4	N/A	76	6,180	3,827
53	289.4	N/A	76	4,666	17,375
54	289.4	N/A	76	4,766	4,261
55	289.8	Right	84	14,727	3,630
56	289.7	Right	84	4,440	2,088
57	285.2	Left	46	5,265	713
58	283.3	Left	45	<3,250	771
59	284.9	Left	46	6,086	760
60	287.7	N/A	61		
60A	287.7	Right	61	8,762	1,330
60B	287.7	Right	61	8,962	1,170
61	287.9	Left	63	5,752	30,437
61A	287.9	Left	63	3,568	11,727
61B	287.9	Left	63	6,286	624
62	287.8	N/A	61		
63	287.9	Right	64	8,762	480
64	287.6	Right	59	8,562	583
65	287.5	Right	60	8,762	943

Stranding Site #	River Mile	River Bank	MHU #	Stranding Flow (cfs)	Stranding Area (ft^2)
66	286.3	Right	53		3,049
67	286.3	Right	53	5,986	924
68	285.4	Right	48	5,460	84,638
69	285.2	Right	47	4,450	2,345
70	285.2	Right	47	5,100	2,669
71	284.3	Right	45	3,664	493
72	283.6	Right	45	12,643	722
73	282.8	Right	43	5,750	364
74	282.6	Right	42	4,591	235
75	281.3	Right	36	<3,250	42,066
76	281.3	Right	36	8,826	5,918
77	281.0	Right	34	6,744	2,341
78	280.6	Right	33	6,672	2,331
79B	280.6	Right	33	8,364	120
79C	280.6	Right	33	8,926	1,691
79A	280.4	Left	31	8,926	693
80	279.9	Right	28		459
81	279.1	Right	26	13,546	1,814
82	273.0	Right	9		702
83	283.1	Left	44		675
84	282.7	Left	43		
85	282.6	Left	41		7,097
86	280.8	Right	34	6,542	2,153
87	280.4	Right	30		2,129
88	280.3	Right	30		1,746

Stranding Site #	River Mile	River Bank	MHU #	Stranding Flow (cfs)	Stranding Area (ft^2)
88A	280.3	Right	30		1,089
89	280.3	Right	30		50
90	280.2	Left	30		650
91	278.5	Left	20	9,333	3,683
92	276.9	Left	14	8,333	1,871
93	275.6	Left	12	15,071	738
94	275.6	Left	12	11,083	675
95	271.7	Right	6		
96	287.6	Right	21	9,406	1,159
97	287.6	Right	21		564

APPENDIX B

LOWER AMERICAN RIVER REDD DEWATERING ANALYSIS